ANNUAL REPORT ON FY98 ONR SPONSORED RESEARCH

Ocean Dynamics

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LONG-TERM GOAL

To gain a more complete understanding of ocean dynamical processes, particularly at fine-scale, through intercomparison of high, mid- and low-latitude observations, both near the sea surface, in the main thermocline, and near the sea floor.

OBJECTIVES

To identify the phenomena involved in the cascade of energy from mesoscales to turbulent scales. To quantify the relationship between fine-scale background conditions and the occurrence of microscale breaking.

APPROACH

Progress is effected through a steady-state cycle of instrument development, field observation and data analysis. The primary instruments employed include Doppler sonar and profiling CTD's. Generically, our instruments produce information which is quasi-continuous in space and time. Measurements typically span two decades in the wavenumber domain. This broad band space-time coverage enables the investigation of multi-scale interactions.

WORK COMPLETED

Direct measurements of ocean turbulence have been feasible for the past 25 years. Turbulence measurements focus on the "aftermath" of breaking events, as opposed to the precursor phenomena which trigger and provide the energy for ocean mixing. In order to identify the fine scale links in the energy cascade, a sense of the time evolution of the flow is required.

We have obtained such information using repeated profiling CTDs and Doppler sonars. During the 1995 Marine Boundary Layer Experiment these devices were deployed from the Research Platform FLIP which was anchored in 1.5 km deep water 30 km west of Pt. Arguello, CA. In the course of MBL, approximately 3600 CTD profiles were obtained, from the surface to 440 m. From the resulting density profiles, a space-time map of breaking events was determined. An event was defined as short-lived simultaneous inversion in the profiles of density, temperature and electrical conductivity. Over 2000 independent events were identified in the MBL data. With continuous velocity and density field observations, the conditions both before and after breaking could be determined. Interpretation was complicated by the significant lateral advection at the MBL site. Nevertheless, significant patterns could be identified.

RESULTS

As expected, there is a significant correspondence between breaking and the occurrence of low Richardson numbers. However, most breaking events occur when the Richardson number (resolved only to 6m vertical scales) is not critical. A better predictor of breaking is the vertical strain, $\gamma \equiv \Delta\eta\ (t,z) / \overline{\Delta\eta}\ (z)$, where $\Delta\eta$ is the instantaneous separation between isopycnal surfaces whose mean separation is $\overline{\Delta\eta}$. Breaking preferentially occurs in regions of large γ, lower than average N^2. The best predictor of mixing is the vertical strain rate $\partial w/\partial z \equiv \partial(\log \gamma)/ \partial t$. The strain rate is associated with groups of small-scale internal waves, with dominant vertical wavelengths of 10-30m. These appear to have intrinsic frequencies between .2 and 5 cph and horizontal wavelengths of hundreds of meters. Their passage through the FLIP sensors is a mix of advection and propagation. The squared strain rate, $(\partial w/\partial z)^2$, is a log-normally distributed random variable and an excellent predictor of overturning.

IMPACT/APPLICATION

We have identified the small scale internal wave packets which are responsible for the dominant breaking at the MBL site. Convective instability appears to be the dominant mixing mechanism. To identify the next step up in scale along the energy cascade it is necessary to determine the climatology of these waves and to understand their dynamical environment and energy source.

TRANSITIONS

The coded pulse technology developed in our group in the last decade is now being considered for implementation by commercial Doppler sonar companies. The sonar developed for MBL was subsequently used in the NSF SHEBA program. It was installed in the Beaufort Sea at 25° N in November 1997. During a major ice shift in early February 1998 the transducers were crushed. Replacement transducers were installed in March and the system subsequently ran until it was removed in October 1998. An excellent picture of under-ice motion in the Western Arctic was obtained.

RELATED PROJECTS

The Marine Boundary Layer observations benefit greatly from the technical legacy of preceding upper ocean programs such as SWAPP, LEADEX and TOGA COARE. In these experiments the instruments and techniques were developed which made MBL possible. Also, the Naval Sea Systems Command provided for a much needed overhaul of the Research Platform FLIP. The renovated FLIP performed quite well in support of MBL.

In turn, the instrument technology developed for MBL has been used in SANDY DUCK and SHEBA. It is anticipated that the aspects of MBL which are unique geographically, such as the tidal and mixing observations of MBL I, can be used to plan a coming series of ONR experiments which hope to quantify the difference between the coastal ocean and the deep sea, at small scales.

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